

# Using Clinically-Enhanced Claims Data to Discern Current Patterns of Inpatient Care and Identify Opportunities for Improvement

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## Abstract

**Background:** The rapid evolution of electronic medical records presents an opportunity to integrate laboratory and pharmacy order data with administrative claims data to yield an enhanced database. This enhanced database would relate drug administration to admission diagnostic information and changes in laboratory test results.

**Methods:** Administrative claims for 2010-2012 from 16 Minnesota hospitals were enhanced by the electronic pharmacy order and laboratory data. A total of 539 patients admitted for congestive heart failure were grouped by admission creatinine, blood urea nitrogen, and brain natriuretic peptide levels. Descriptive equations were derived relating admission laboratory profiles to two-day administration of furosemide and to corresponding drug administration to 361 patients with good therapeutic responses.

**Results:** Statistically-significant, clinically-plausible relationships between furosemide administration, admission laboratory test results, and therapeutic responses were established. Patients with high admission creatinine levels but lower than threshold BUN-to-creatinine and BNP levels often were receiving suboptimal two-day doses of furosemide.

**Conclusions:** High-quality hospital claims databases enhanced with laboratory and pharmacy order data can be used to characterize current inpatient drug therapy and guide efforts to improve clinical effectiveness.

**Keywords:** Clinical practice patterns/evidence-based practice; Acute inpatient care; Pharmaceutical use; Quality improvement (interventions); Clinically-enhanced claims data

## Introduction

Standard hospital discharge claims databases contain detailed information about principal and secondary diagnoses, whether diagnoses were present-on-admission or hospital-acquired, the dates of admission and discharge, and which patients died in the hospital. They also contain information about important inpatient procedural interventions and dates of performance. More detailed information about hospital care may be obtained by linking hospital claims to claims for inpatient professional services. Enhancement of hospital claims with numerical laboratory data can assist in evaluating the accuracy of diagnostic coding, improve the accuracy of measures of risk-adjusted patient outcomes, and provide information about improvement or deterioration of the underlying clinical status of the patient [1-6]. Using these data, it is possible to link risk-adjusted inpatient adverse outcomes rates to professional services and procedural interventions.

In contrast to inpatient diagnoses and procedures, claims databases contain virtually no information about drugs administered to hospitalized patients. Comparative outcomes of care could be assessed better if pharmaceutical interventions were detailed in the same way that procedural information is documented in the discharge abstracts. The current study represents an initial effort to add inpatient pharmacy order data to hospital claims data that has been enhanced with inpatient numerical laboratory test results. The study provides a concrete illustration of how this type of clinically-enhanced claims database can support descriptive analyses of current patterns of inpatient drug administration and demonstrates how these data can be used to improve the effectiveness of inpatient pharmaceutical therapy.

## Methods

### Databases

Analyses were performed on clinically-enhanced hospital claims data from 16 Minnesota hospitals for 539 patients hospitalized for congestive heart failure (CHF) between January 2010 and December 2012 who were treated with furosemide during their first day of hospitalization. All patients had documented results for laboratory tests for serum creatinine, blood urea nitrogen (BUN) and brain natriuretic peptide (BNP) on the day of admission and between two and five days after admission.

Laboratory test results were acquired from electronic data repositories within participating hospitals and then linked to corresponding hospital claims data in the Minnesota Hospital Association (MHA) hospital discharge claims database using encrypted unique patient identifiers as described previously [7].

Pharmacy order data from the electronic data repositories were extracted, assigned encrypted unique patient identifiers to facilitate linkage to corresponding hospital claims and numerical laboratory

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data, and transmitted to MHA either in a flat (Microsoft Excel) file or Health Level 7 (HL7) format. HL7 is a comprehensive framework that establishes standard formats for the transmission of electronic health information [8]. Required pharmacy fields included drug names (as listed in each hospital's formulary), National Drug Codes (NDC), dosages, routes and frequencies of administration, start dates and times, and durations of administration (either as durations or as stop dates). Upon receipt of these data, MHA performed data checks for completeness and internal consistency. Dosages, routes, times, and frequencies of administration were converted into a standardized set of units and descriptors. NDC were mapped to RxNorm (U.S. National Library of Medicine 2014) [9] which served as the primary classification system for data storage, retrieval and analysis. Only cases hospitalized for CHF that had all required laboratory and pharmacy data elements documented in the MHA's clinically-enhanced hospital claims database were included in this demonstration of how these data can be used to characterize current hospital practice patterns and identify potential opportunities to improve clinical care.

### Data analysis

Each case was assigned to one of a mutually-exclusive set of categories based on (1) whether the admission creatinine level was less than 2.0 mg/dL, (2) whether the admission BUN was less than 25 mg/dL or the ratio of the admission BUN to the admission creatinine was 20 or less, and (3) whether the admission BNP was less than 1,000 pg/ml. Stepwise backward linear regression was used to identify categories of cases that received doses of furosemide during the first two days of hospitalization that differed significantly from doses administered to a reference population whose admission laboratory test results did not exceed any of these three thresholds. The resulting descriptive equation was used to assign a current standard therapeutic two-day dose (CSTD) of furosemide to each case.

Intermediate outcomes of hospital care were assessed by comparing the first result of each laboratory test obtained after the second day of hospitalization, or the last test result obtained when a test was not performed after the second hospital day, to the corresponding admission test result. A good intermediate outcome was defined as a follow-up BNP that was lower than the admission BNP and one of the following two scenarios: (1) when either the admission BUN was less than 25 mg/dL or the admission BUN-to-creatinine ratio was 20 or less, either a follow-up BUN less than 30 mg/dL or a follow-up BUN-to-creatinine ratio of 24 or less, or (2) when the admission BUN was greater than or equal to 25 mg/dL and the admission BUN-to-creatinine

ratio was greater than 20, a follow-up BUN-to-creatinine ratio that was 120 percent or less than the admission BUN-to-creatinine ratio.

The set of cases with good intermediate outcomes, as defined in the preceding paragraph, were used to determine whether computed CSTDs of furosemide were optimal in this subpopulation. Stepwise forward linear regression was employed to determine whether any of the categories employed to develop a descriptive equation for CSTDs would significantly enhance the correlation between computed CSTDs and two-day doses of furosemide actually administered to cases with good intermediate outcomes.

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### Results

Admission serum creatinine (normal values  $\leq 1.2$  mg/dl) ranged from 0.5 to 9.2 mg/dL (median=1.3; mean=1.47; standard deviation [SD] = 0.88). Admission BUN (normal value = 6-20 mg/dl) ranged from 5 to 114 mg/dL (median=27; mean=32.9; SD=19.4). Admission BNP (normal value  $\leq 100$  pg/ml) ranged from 42 to 20,000 pg/ml (median=896; mean=1,299; SD=1,424). During the first two days of hospitalization for CHF, patients received from 10 to 1,040 mg of furosemide (median=90; mean=150.7; SD=158.4) of 539 patients hospitalized for CHF, 17.1 percent had admission creatinine levels greater than or equal to 2.0 mg/dL, 41.6 percent had admission BUN levels greater than or equal to 25 mg/dL and admission BUN-to-creatinine ratios greater than 20, and 45.1 percent had admission BNP levels greater than or equal to 1,000 (Table 1). In contrast, 31.9 percent of patients had admission test results that did not exceed any of these three thresholds. Patients with high admission creatinine levels received significantly more furosemide than patients whose admission creatinine levels were less than 2.0 mg/dL.

Backwards stepwise linear regression using all 539 cases in the analytic database resulted in a final predictive equation with an intercept of 135.1 mg of furosemide and the following three statistically significant independent variables based on admission laboratory values: (1) only creatinine exceeds threshold (coefficient=146.2 mg); (2) only creatinine and BNP exceed threshold (coefficient=54.9 mg); and (3) all three test results exceed threshold (coefficient=53.5 mg).

Forwards stepwise linear regression limited to the 361 cases that met criteria for a good intermediate outcome resulted in a regression

	Inclusion Criteria			Cases		Furosemide (mg/2 days)		
	1 <sup>†</sup>	2 <sup>††</sup>	3 <sup>†††</sup>	Number	% Total	Mean	SEM <sup>‡</sup>	P <sup>‡‡</sup>
All Cases	+/-	+/-	+/-	539	100.0%	145.6	5.9	
No admission risk factors	-	-	-	172	31.9%	118.4	8.2	<0.01
High admission creatinine	+	+/-	+/-	92	17.1%	200.0	18.5	<0.01
High admission BUN* and BUN/Creatinine	+/-	+	+/-	224	41.6%	152.2	9.9	NS
High admission BNP*	+/-	+/-	+	243	45.1%	148.5	9.2	NS
Good intermediate outcome**	+/-	+/-	+/-	361	67.0%	143.9	7.0	NS

\* BUN = Blood Urea Nitrogen; BNP = Brain Natriuretic Peptide

\*\* Day 3 BNP < admission BNP and if criterion 2 positive: Day 3 BUN < 30 or BUN/Creatinine  $\leq 24.0$  or if criterion 2 negative: Day 3 BUN/Creatinine  $\leq 1.2$  \* admission BUN/Creatinine

<sup>†</sup> Creatinine  $\geq 2.0$

<sup>††</sup> BUN  $\geq 25$  and BUN/Creatinine  $>20.0$

<sup>†††</sup> BNP  $\geq 1,000$

<sup>‡</sup> SEM = standard error of the mean

<sup>‡‡</sup> Probability furosemide dosage differs between qualifying and non-qualifying cases; NS = not statistically significant

**Table 1:** Amount of furosemide administered during the first two days of hospitalization for congestive heart failure.

equation with an intercept of 36.4 mg of furosemide and the following two statistically significant independent variables: (1) the predicted amount of furosemide administered to each patient based upon the previously derived regression equation (coefficient=0.767); and (2) admission test results with only creatinine levels exceeding threshold values (coefficient=141.9 mg).

When results of these two analyses were combined, 2-day amounts of administered furosemide associated with good outcomes were 394 mg when only admission creatinine values exceed threshold, 182 when only admission creatinine and admission BNP values exceed threshold, 181 when all three test values exceed threshold, and 140 in all other cases.

## Discussion

The scope and depth of analyses reported in this manuscript were severely limited by difficulties encountered in developing and implementing systems to acquire, format, transmit, integrate, clean, and interpret pharmacy order data from participating hospitals' electronic data repositories. As with the collection of laboratory data, [7] hospital resource availability and competing information technology priorities were important obstacles in obtaining complete, properly-formatted pharmacy order data. Hospital personnel had particular difficulty providing NDC data required to assign RxNorm identifiers and in documenting when orders were discontinued. MHA staff worked closely with all participating hospitals to make data collection and transmission as easy as possible and provided on-site assistance upon request. Despite these efforts, only a small sample of high-quality inpatient pharmacy order data was available for analyses of clinical processes and outcomes.

Because of these data limitations, analyses focused on demonstrating how numerical laboratory and pharmacy order data could be combined to relate clinical practice to admission diagnostic information and changes in patients' laboratory test results and did not attempt to provide definitive information about participating hospitals' current treatment of acute decompensated heart failure or about how their clinical outcomes might be improved. In contrast to traditional clinical research designed to evaluate the use of diuretic therapy in patients with CHF, [10-15] this study was designed to illustrate the potential of alternative analytic approaches that employ clinically-enhanced claims data to provide insight into factors that influence how diuretics are being used to treat acute episodes of CHF and to compare standard treatment decisions to treatment decisions associated with good clinical outcomes.

Instead of beginning with a predetermined set of best practice guidelines, current practice was characterized by relating the amount of drug administered to patients and their admission laboratory test results. This approach parallels methods advocated by proponents of statistical process control and continuous quality improvement [16,17]. Despite the small size of the analytic data set, clear, statistically-significant, clinically-plausible relationships between drug administration and admission laboratory test results were established.

To explore how standard care differed from "best-practice," a second descriptive equation was derived using only cases that had favorable outcomes. This new equation included drug dosages based on the predictive model for current therapy and adjustments to these dosages for each case category (as defined by admission laboratory test results) only when these adjustments were statistically significant additions to a previous model. Again, this analysis strongly suggested that, in this small sample, patients with high admission creatinine levels

but lower than threshold BUN-to-creatinine and BNP levels often were receiving less-than-optimal two-day doses of furosemide. These findings clearly demonstrate the potential value of hospital claims data enhanced with numerical laboratory and pharmacy order data in characterizing current drug therapy, relating it to clinical outcomes, and suggesting how treatment might be altered to improve therapeutic results.

The selection of RxNorm to classify drugs in this clinically-enhanced claims database was based on several considerations. Because individual NDC often reflect extremely small differences in pharmaceutical preparations, RxNorm identifiers provide superior grouping of pharmacologically similar agents while permitting analyses at multiple levels, including individual drugs, drug classes, dosages, and routes of administration. RxNorm is increasing being used throughout healthcare as evidence by its selection as the medication code set for "Meaningful Use" [18] and by its inclusion in major pharmacy databases such as First Databank and Micromedex [19,20]. RxNorm is maintained by the National Library of Medicine and updated weekly as new medications are released [8].

Although it would have been preferable to monitor actual drug administration, very few hospitals currently maintain electronic records of drug administration. On the other hand, electronic records containing inpatient drug orders are almost universally available. Until electronic documentation of drug administration is commonplace, medication orders can serve as a useful proxy when applied to commonly used drugs delivered as single doses or on fixed schedules.

## Conclusion

The current study demonstrated how a complete high-quality hospital claims database enhanced with numerical laboratory and pharmacy order data can be used to characterize current inpatient drug therapy and guide efforts to improve clinical effectiveness. Future developmental efforts should focus on implementing standard methods of incorporating inpatient pharmacy data into clinically-enhanced hospital claims databases and extending current research to include risk-adjusted patient-centered outcomes in larger populations of patients hospitalized for diseases for which acute drug therapy is an important part of their inpatient care.

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